II. CHEMISTRY AND PHYSICS.

EXPERIMENTS ON THE RELATIVE HEATING POWER OF COAL AND ILLUMINATING GAS.

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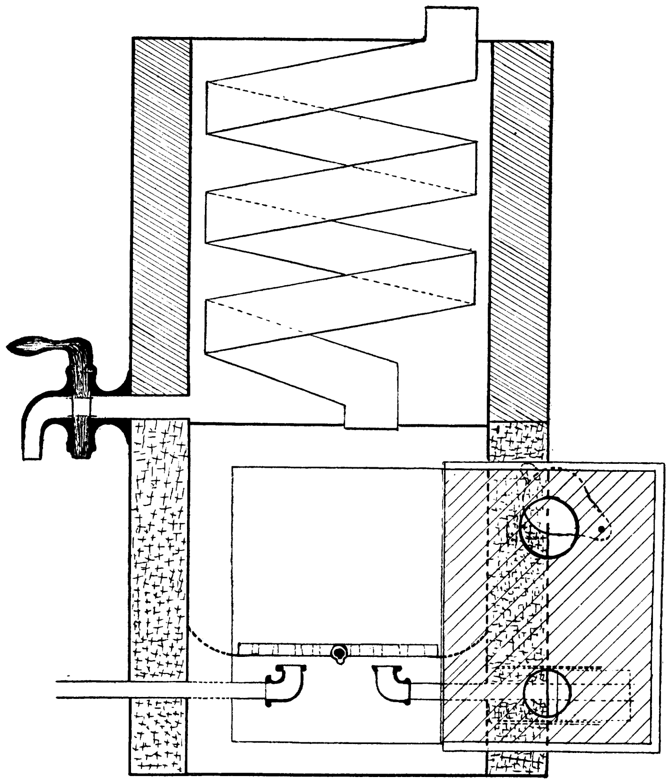
The problem that was brought to my notice some time ago was to find the relative fuel value of coal and natural gas, and, by this means, to determine how much per thousand should be paid for the latter so that the cost of fuel should be the same as if coal was used. Although we have the analysis of the natural gas as found in the Kansas gas fields,* and the composition of the coals of the state,† yet all attempts to arrive at the relative value of the two fuels from a theoretical standpoint were unsatisfactory, for the question was a practical one, and could be solved only by the use of a method that would imitate actual experience.

At first a crude apparatus was designed in which a weighed amount of water was boiled with a given quantity of fuel of each kind, but the loss of heat was so great that it was deemed advisable to construct an apparatus especially for the purpose. The furnace, as finally designed and used, is represented on next page. It consists of a cylinder of galvanized iron two feet high and fourteen inches in diameter. Inside of this is another cylinder ten inches in diameter and the annular space between the two is filled with charcoal, sawdust, or asbestos packing. Both these cylinders are soldered onto the base and onto the connecting ring at the top. A bottom is soldered into the inner cylinder eleven and one-half inches from the base. Inside the vessel thus formed is a one-and-three-fourths-inch tin pipe coiled three times, the upper end opening above the top of the vessel and the lower end passing through the bottom. This is the flue to carry off the products of combustion. Below the bottom of the kettle is a small grate which may be removed and its place supplied by the burner of a gas stove. There is a door lined with asbestos on one side of the lower part of the furnace. Just below the grate are two one-fourth-inch iron pipes terminating on the inside, with elbows turned upwards, and passing entirely through the apparatus to the outside. There is also a pipe leading from the bottom of the inside vessel closed by a spigot on the outside, so that the water may be quickly withdrawn from the inner vessel. A thermometer hangs in the water.

The apparatus is used as follows: The inner vessel is filled with water, and is then heated to boiling by means of the gas-burner; this water is quickly drawn out by the spigot and weighed on a moderately accurate balance; with the vessel in which it is contained it weighs about twenty-four pounds. The water is immediately, while still hot, returned to the boiler, the gas is relighted and the amount of gas consumed is carefully measured by a meter that reads to hundredths of cubic feet. The gas is allowed to burn for an hour or more, and then the water is quickly drawn off and weighed. The difference gives the loss by evaporation, which is calculated per cubic foot of gas.

In order to determine the heating power of the coal, the vessel is again filled

* Kan. Univ. Quar., vol. IV, pp. 1-14. † Transactions Kans. Acad. of Sci., vol. XI, pp. 46-49.



Apparatus for Testing Relative Heating Power of illuminating Gas and Coal.

and the water taken out and weighed when boiling hot. A weighed amount of coal is put on the grate and quickly ignited, and its burning is accelerated by the use of a foot-blower attached to the two pipes coming to the outside of the apparatus, as previously mentioned. The products of combustion are carried up through the one-and-three-fourths-inch pipe, which, in their passage, heat the water. Of course there is considerable smoke, and this is carried off by a two-and-one-half-inch pipe which fits over the smaller one. When the coal is nearly consumed that which remains is raked out and weighed, the water is drawn off and weighed, and the calculation is made with reference to the coal consumed.

While it is admitted that the apparatus is liable to some errors, yet it is devised with the object of imitating, as well as possible, the natural conditions which hold in the consumption of fuel under a boiler. The tests are comparative; and in neither case is all the heat utilized.

Some of the results obtained were as follows:

One cubic foot of gas will evaporate	*a*	0.45	lb. of water.
	a	0.46	"
	b	0.36	"
	c	0.39	"
	d	0.43	"
	e	0.36	"

These tests were taken on different days, when there was a different degree of humidity in the air, and when the temperature of the room was different. It was noticed also that the rate at which the gas burned had a decided influence on the economy of the operation. A rate of from six to twelve feet per hour was used, but the medium between these was probably most efficient. The amounts of water evaporated by the coal were as follows:

One pound of coal will evaporate	*a*	5.9	lbs. of water.
	b	3.9	"
	c	4.06	"
	d	4.5	"
	e	3.87	"

The only satisfactory methôd of using the apparatus is to test it first by the use of gas, and then under the same atmospheric conditions to test it with the coal. Hence, although the above tests seem to differ greatly, they do not differ so much when taken in connection with the corresponding gas test, made at the same time.

From the above tests, as we have ascertained the amount of water that one cubic foot of gas will evaporate and the amount of water that one pound of coal will evaporate, it is not difficult to calculate the value of one ton of coal in terms of gas. The results are as follows:

One ton of coal is equivalent to	*a*	23,000	cubic feet gas.
	b	21,600	"
	c	20,800	"
	d	20,900	"
	e	21,500	"
Average		21,500	

The experiments above noted were made with the ordinary illuminating gas. This gas, delivered to the consumers of the city of Lawrence, Kan., on December 6, 1894, had at that time the following composition:

Carbon dioxid (CO_2)	1.22
Olefiant gas and similar hydrocarbons	5.30
Oxygen (O)	.22
Carbon monoxid (CO)	7.50
Marsh-gas, methan (CH_4)	38.11
Hydrogen (H)	47.65
Total	100.00

The composition of the natural gas of the state may be fairly well shown by the analysis of a sample from the Neodesha fields:*

Carbon dioxid (CO_2)	1.00
Olefiant gas and similar hydrocarbons	.22
Oxygen (O)	.65
Carbon monoxid (CO)	.50
Marsh-gas, methan (CH_4)	90.56
Hydrogen (H)	0.00
Nitrogen (N)	7.07
Total	100.00

*Kan. Univ. Quar., vol. IV, pp. 1-14.

Comparing these two gases, it is evident that the illuminating gas used has a greater heating power than the natural gas, for in the illuminating gas there is 47.65 per cent. of hydrogen, and the heat units yielded by hydrogen are 34.462; while the chief constituent of the natural gas is marsh-gas (CH_4), which yields only 13.063 heat units, and this is practically the only heat-producing substance in the natural gas, all other gases being present in such small quantities.

In the tests upon coals, the first four were made upon Leavenworth coal, and the last two on Cañon City coal. It is evident that the process is not suited to determine the relative heating value of different samples of coal, and, indeed, that is not the intention.

If the average result obtained is taken, namely, that one ton of coal is equivalent in heating power to 21,500 cubic feet of gas, then, with Leavenworth coal at $2.50 per ton, gas would have to be sold at about twelve cents per thousand to be the equivalent in cost of the coal. Of course, as the coal increases in price, the cost of gas may also be raised proportionately. There is no doubt that the natural-gas producers in some of our districts could afford to furnish gas at this figure, but in others the price would be too low.

In the consideration of the relative heating power of the two fuels, no account is taken of the extreme convenience, wholesomeness and cleanliness of gas, nor of the fact that it can be lighted at any time when it is needed, and as soon as the work is done it can be extinguished. For convenience, then, there is nothing to equal gas; but this fuel must be sold at an extremely low price to compete economically with coal.

Lawrence, December 26, 1899.

ON THE EFFECT OF OXYGEN UPON ANIMAL LIFE.

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The general view of those who think of it at all is that an atmosphere of pure oxygen would be most deleterious to animal life. That this view is not confined to the unscientific may be readily shown by reference to various authors. The following may be cited as typical:

J. F. W. Johnston, in his "Chemistry of Common Life," published in 1869, says: "Animals breathe oxygen with an increase of pleasure; but it excites them, quickens their circulation, throws them into a state of fever, and finally kills them by an excess of excitement. They live too rapidly in pure oxygen gas, and burn away in it like the fast-flaring candle. Did the atmosphere consist of oxygen only, the lives of animals would be of most brief duration."

C. W. Kimmins, in his "Chemistry of Life and Health," 1892, says: "The removal of nitrogen from the atmosphere would be as fatal as the removal of oxygen; and universal death would be accompanied by universal conflagration."

Gray says: "The Creator has adapted the atmosphere to the support of life, as anything which destroys the relation thus established renders it deleterious to the animal constitution."

Dr. B. W. Richardson seems to be one of the few who have made experiments as well as statements. He confined mice in a chamber of oxygen. In the first experiment, conducted at a temperature of fifty-five degrees F., the mouse was dead at the end of four hours. The second experiment was conducted at a temperature of seventy-five degrees F., and the mouse was taken out in deep sleep